Low-Pt-Content Anode Catalyst for Direct Methanol Fuel Cells

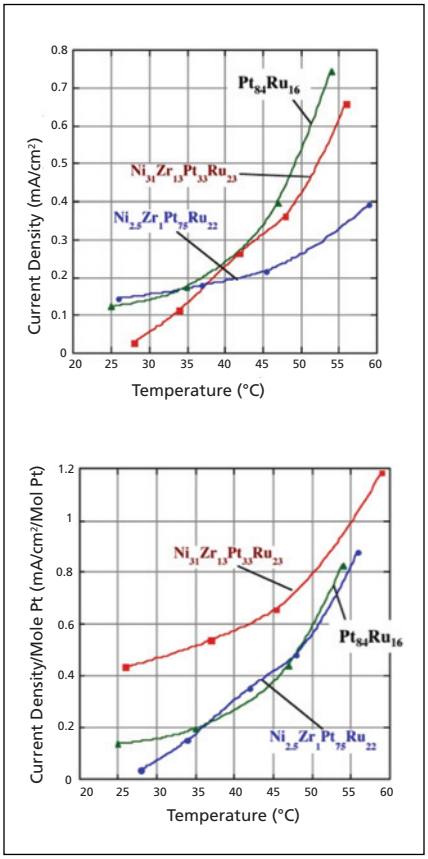
The costs of fuel-cell anodes could be reduced substantially.

NASA's Jet Propulsion Laboratory, Pasadena, California

Combinatorial experiments have led to the discovery that a nanophase alloy of Pt, Ru, Ni, and Zr is effective as an anode catalyst material for direct methanol fuel cells. This discovery has practical significance in that the electronic current densities achievable by use of this alloy are comparable or larger than those obtained by use of prior Pt/Ru catalyst alloys containing greater amounts of Pt. Heretofore, the high cost of Pt has impeded the commercialization of direct methanol fuel cells. By making it possible to obtain a given level of performance at reduced Pt content (and, hence, lower cost), the discovery may lead to reduction of the economic impediment to commercialization.

In the experiments, alloys of various Pt/Ru/Ni/Zr compositions and Pt/Ru compositions were made by co-sputter deposition onto patterned Au on glass substrates at various positions relative to a $Pt_{40}Ru_{60}$ and $Ni_{70}Zr_{30}$ sputter targets (the numbers denote atomic percentages). X-ray diffraction analysis of the alloys led to the conclusion that the quaternary alloy most likely consisted of one or two crystalline phases characterized by grain sizes of 1 to 5 nm.

The electrochemical performances of the alloys were tested using both cyclic voltammetry and potentiostatic current measurements. The most promising Pt/Ru/Ni/Zr alloy had a composition of $Pt_{33}Ru_{23}Ni_{30}Zr_{13}$. Comparative potentiostatic tests of $Pt_{33}Ru_{23}Ni_{30}Zr_{13}$ and an optimized, state-of-art $Pt_{84}Ru_{16}$ catalysts were performed (in a solution of 1M methanol + 1M sulfuric acid at temperatures ranging from 25 to 60 °C). The results of these tests, plotted in the figure, show that the current density [after 5 minutes at 0.7 V vs. NHE (normal hydrogen electrode)] for $Pt_{33}Ru_{23}Ni_{30}Zr_{13}$ met (as normalized to test structure area), or exceeded (if normalized to surface Pt atoms), the current densities of the state-of-art Pt-Ru under the same test conditions. These data indicate that the new quaternary alloy induced a significantly higher Pt surface site utilization. X-ray photoelectron spectroscopy data indicate that the Pt electron structure in the quaternary material was also very different from that observed in the Pt-Ru alloys.



Plotted Test Results compare current densities for $Pt_{33}Ru_{23}Ni_{30}Zr_{13}$ with current densities of the state-of-art Pt-Ru under the same test conditions.

This work was done by Sekharipuram Narayanan and Jay Whitacre of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Graphite/Cyanate Ester Face Sheets for Adaptive Optics

Unlike glass face sheets, these would be nearly unbreakable.

Marshall Space Flight Center, Alabama

It has been proposed that thin face sheets of wide-aperture deformable mirrors in adaptive-optics systems be made from a composite material consisting of cyanate ester filled with graphite. This composite material appears to offer an attractive alternative to low-thermal-expansion glasses that are used in some conventional optics and have been considered for adaptive-optics face sheets.

Adaptive-optics face sheets are required to have maximum linear dimensions of the order of meters or even tens of meters for some astronomical applications. If the face sheets were to be made from low-thermal-expansion glasses, then they would also be required to have thicknesses of the order of a millimeter so as to obtain the optimum compromise between the stiffness needed for support and the flexibility needed to enable deformation to controlled shapes by use of actuators.

It is difficult to make large glass sheets having thicknesses less than 3 mm, and 3-mm-thick glass sheets are too stiff to be deformable to the shapes typically required for correction of wavefronts of light that has traversed the terrestrial atmosphere. Moreover, the primary commercially produced candidate low-thermal-expansion glass is easily fractured when in the form of thin face sheets.

Graphite-filled cyanate ester has relevant properties similar to those of the low-expansion glasses. These properties include a coefficient of thermal expansion (CTE) of the order of a hundredth of the CTEs of other typical mirror materials. The Young's modulus (which quantifies stiffness in tension and compression) of graphite-filled cyanate ester is also similar to the Young's moduli of low-thermal-expansion glasses. However, the fracture toughness of graphite-filled cyanate ester is much greater than that of the primary candidate low-thermal-expansion glass. Therefore, graphite-filled cyanate ester could be made into nearly unbreakable face sheets, having maximum linear dimensions greater than a meter and thicknesses of the order of a millimeter, that would satisfy the requirements for use in adaptive optics.

This work was done by Harold Bennett and Joseph Shaffer of Bennett Optical Research, Inc. and Robert Romeo of Composite Mirror Applications, Inc. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32337-1.

Atomized BaF_2-CaF_2 for Better-Flowing Plasma-Spray Feedstock

Water atomization is better suited to high-volume production of metal fluoride than conventional methods.

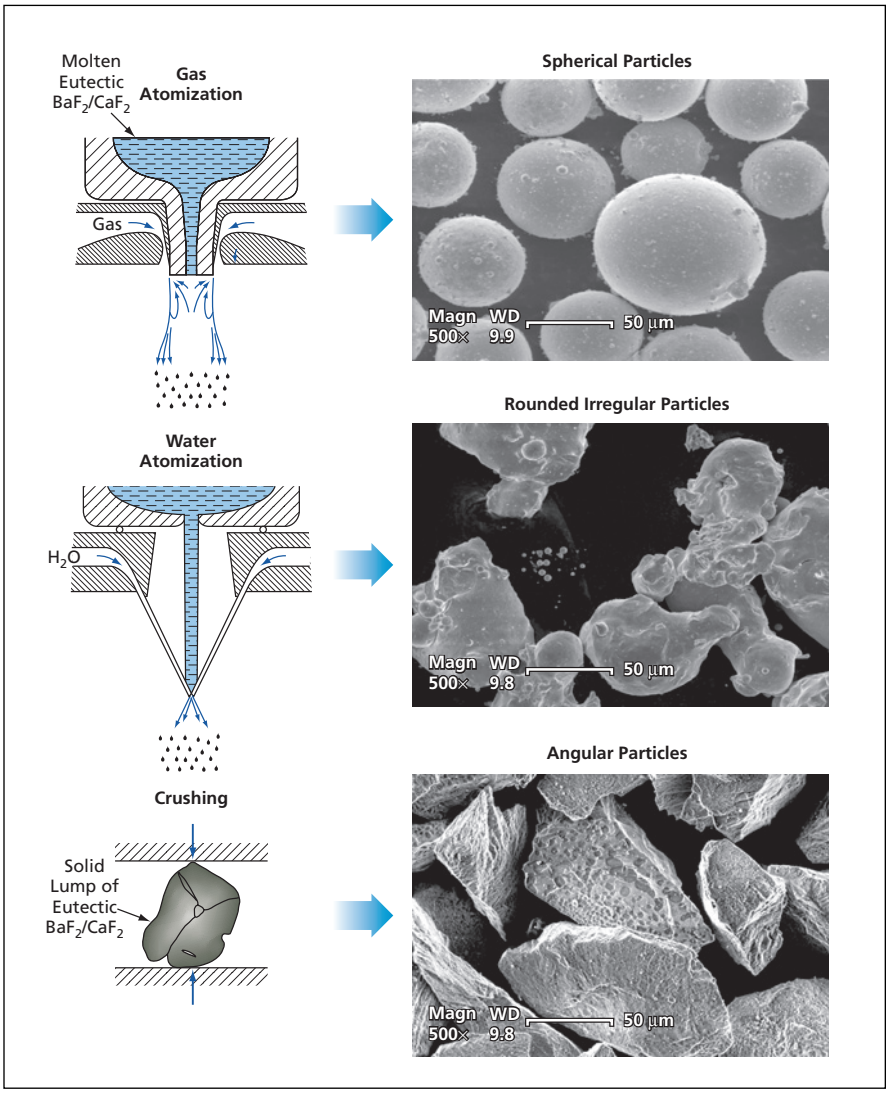
John H. Glenn Research Center, Cleveland, Ohio

Atomization of a molten mixture of BaF_2 and CaF_2 has been found to be superior to crushing of bulk solid BaF_2-CaF_2 as a means of producing eutectic BaF_2-CaF_2 powder for use as an ingredient of the powder feedstock of a high-temperature solid lubricant material known as PS304. Developed to reduce friction and wear in turbomachines that incorporate foil air bearings, PS304 is applied to metal substrates by plasma spraying. The constituents of PS304 are:

- An alloy of 80 weight percent Ni and 20 weight percent Cr,
- Cr_2O_3,
- Ag, and
- The BaF_2-CaF_2 eutectic — specifically, 62 weight percent BaF_2 and 38 weight percent CaF_2.

The superiority of atomization as a means of producing the eutectic BaF_2-CaF_2 powder lies in (1) the shapes of the BaF_2-CaF_2 particles produced and (2) the resulting flow properties of the PS304 feedstock powder: The particles produced through crushing are angular, whereas those produced through atomization are more rounded. PS304 feedstock powder containing the more rounded BaF_2-CaF_2 particles flows more freely and more predictably, as is preferable for plasma spraying.

Two well-known atomization processes (gas atomization and water atomization) have been investigated, in comparison with crushing, as means of producing eutectic BaF_2-CaF_2 powders (see figure). The particles produced by gas atomization are the most nearly spherical, but each batch contains only a small proportion of particles in the



Water Atomization produces particles intermediate in shape to those produced by gas atomization and crushing. Water atomization may be economically the most advantageous of the three techniques.